S&T Implications for Net Centric Operations

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Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JUN 2004		**00-00-2004 to 00-00-2004**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
S&T Implications for Net Centric Operations	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Raytheon Net Centric Systems,6225 Brandon Avenue Suite 230,Springfield,VA,22150-2519**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**37**	

Abstract

The evolving environment for Net Centric Operations (NCO) is changing the requirements and capabilities that are needed for successful military and civil operations. This in turn is demanding science and technology developments of new enabling technologies with associated NCO capabilities. The Office of Naval Research (ONR) has studied these needs and has developed a Technical Taxonomy and associated shortfalls for Naval Net Centric Operations. This paper discusses that taxonomy and provides an examination of eight technology areas that are required to support five enabling functions necessary for Net Centric Operations. The taxonomy can be found on the ONR web site- http://www.onr.navy.mil/02/baa/expired/03_007/default.asp (Reference 1)

1.0 Introduction

For purposes of consistency, here is background on FORCEnet from the February, 2003 Naval Institute Proceedings (Reference 2). "ForceNet will enhance dramatically how the Navy acquires, shares, and capitalizes on information superiority to generate transformational combat effectiveness. It has its roots in the visionary work of the Chief of Naval Operations' Strategic Studies Group based in Newport, Rhode Island. After years of research and concept generation, the Strategic Studies Group defined ForceNet as "the operational construct and architectural framework for naval warfare in the information age that integrates warriors, sensors, networks, command and control, platforms, and weapons into a networked, distributed combat force that is scalable across all levels of conflict from seabed to space and sea to land." ForceNet implements the theory of network-centric warfare.

Developing ForceNet will involve designing and implementing a network architecture that includes standard joint protocols, common data packaging, seamless interoperability, and strengthened security. It requires identifying and prioritizing capability investments within and across joint, interagency, and international programs. Most importantly, it will emphasize people as the center of ForceNet development, so that technological advances support increasingly rapid and accurate decision making. "

"The goal of ForceNet is to arm our forces with superior knowledge, leading to increased combat power. In pursuit of this goal, ForceNet will provide a comprehensive network of sensors, analysis tools, and decision aids to support the full array of naval activities, from combat operations to logistics and personnel development. The focused, timely, and accurate data delivered by ForceNet will help leaders at every level by allowing them to draw on vast amounts of information and share the resultant understanding. This will increase the joint force's ability to synchronize activities throughout the battle space to achieve the greatest impact."

2.0 Discussion of the Technical Taxonomy

The Navy has developed a process for the selection of R&D to support Net Centric Operations evolution and transformation. The figure below shows the process that ONR has pursued to identify NCO critical operational capabilities and associated S&T. The process is driven from military operational capabilities. It then identifies functional capabilities and associated required enabling technologies. This process allows the operational capabilities to be prioritized, the functional capabilities to be prioritized and finally the S&T enablers can be prioritized. The process is iterative to ensure identification and convergence of technology enablers that will satisfy operational needs

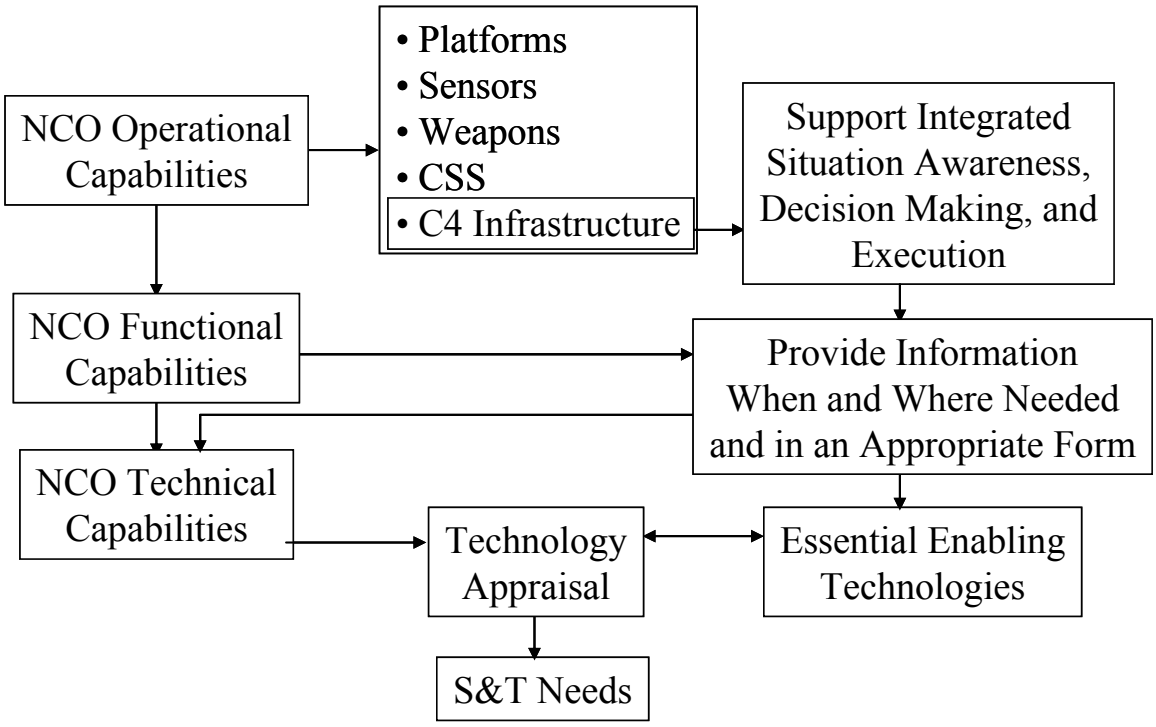

Figure 1. S&T investment Process for Net Centric Operations

Figure 2 shows the major operational capabilities that must be satisfied to support Naval Net Centric Operations. The major operational capabilities are

- Situational Awareness and Understanding
- Planning and Force Management
- Direction, Action, Synchronization and Control

These operational capabilities are the drivers that are used in the S&T process selection shown in the upper left-hand portion of Figure 1

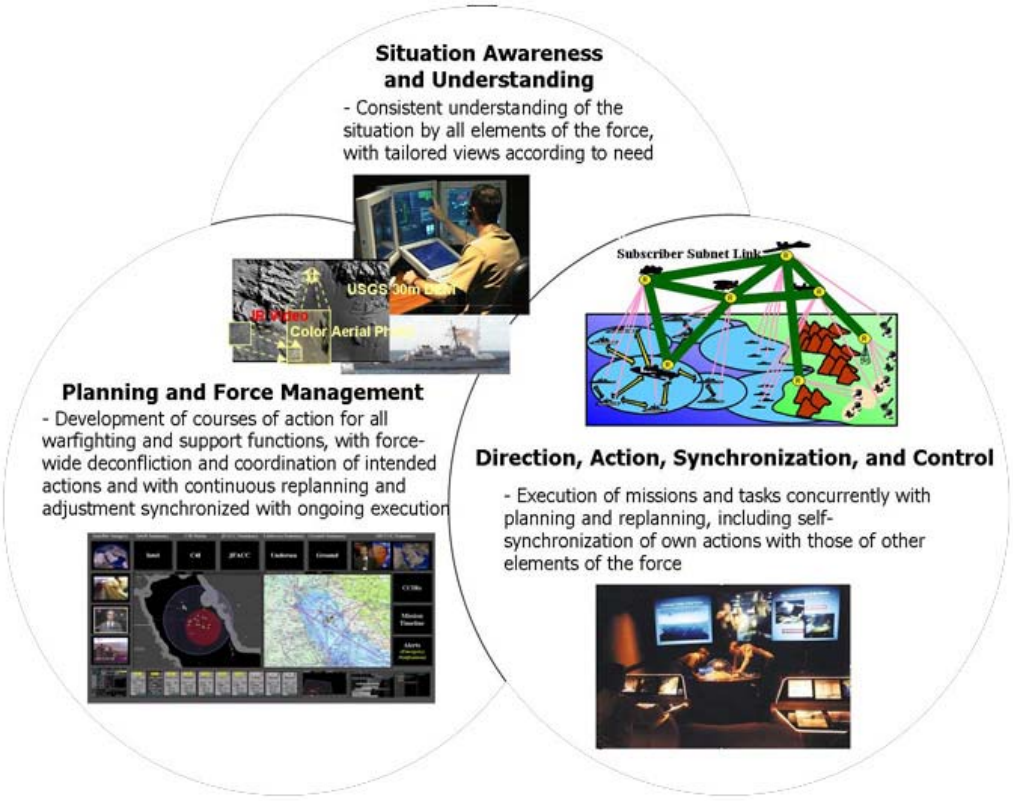

Figure 2. "Operational Capabilities for Net Centric Operations"

The five NCO enabling functions to support FORCEnet are listed below:

1. Universal, seamless, robust communications, connectivity and network service management
2. Assured information integrity
3. Effective information processing, assessment, sharing/collaboration, presentation, and navigation
4. User focused information management and dissemination/communications
5. Empowered disadvantaged personnel and systems

These five areas provide the essence of what is needed to achieve the necessary operational levels and capabilities depicted in Figure 2. The next step was to identify the enabling technologies that are needed to achieve the five enabling functions listed above. There were eight enabling technologies identified as being key to achieving the five enabling functions for FORCEnet and NCO. In this way, the enabling technologies can be related directly to the NCO enabling functions and they can be benchmarked in quantifiable terms to determine the degree of satisfaction of the Navy's needs.

The eight enabling technology areas are listed below:

1. Reliable communications and infrastructure management
2. Information distribution management
3. Geographically distributed, computing infrastructure
4. Situation understanding
5. Automated adaptive dynamic planning
6. Human machine interface
7. Information assurance and information operations
8. Modeling and simulation

These eight enabling technology areas can be decomposed as shown below:

1. Reliable communications and infrastructure management
    - Data Transport and Transmission Systems/Data Links
    - Networking
    - Infrastructure and Computational Resource Management

2. Information distribution management
    - Interoperability Software for (for legacy networks)
    - Information Access and Delivery Software

3. Geographically distributed, computing infrastructure
    - Electronic Devices and Components (disadvantaged user and remote sensors
    - Adaptive Network Computing Management and Services
    - Power Sources (disadvantaged user, autonomous vehicles and remote sensors)

4. Situation Understanding
    - Information Integration Fusion and Correlation for current ISR systems, sensors and open sources
    - Computer Aided Inferencing and Reasoning
    - Autonomous Intelligent Vehicles and Platforms
    - Collaborative Environment
    - Pervasive Computing/Ubiquitous Computing
    - Remote Equipment Diagnostics
    - Augmented Reality

5. Automated Adaptive Dynamic Planning
    - Decision Support Systems
    - Cooperative Software Agents
    - Autonomous Intelligent Vehicles and Platforms
6. Human-Machine Interface (including disadvantaged users)
    - Visualization of Operational Situations and Plans
    - Explanation Agents
    - Alerting and Cueing Agents (for system monitoring and control)
    - Natural Language and Foreign Language Understanding
    - Hands-Free Human-System Interface
    - I/O in Stressing Environments (Noise, Motion, etc.) for Mobile Field Operators
    - Computer Aided Reasoning
    - Augmented Reality

7. Information Assurance and Information Operations

- Confidentiality
- Authentication
- Audit and Analysis of Network Activities
- Integrity
- Network Traffic Processing and Data Base Interaction Analysis
- Ensuring Trusted Systems
- Offensive Information Operations
- Computer Aided Reasoning/Pervasive Computing
- Detection of Covert Information

8. Modeling and Simulation
    - Situation Awareness
    - Course of Action Evaluation
    - Interoperability

The above process and identification of enablers is called the NCO Technical Taxonomy. The Technical Taxonomy, in this context, is a hierarchy of information technologies that support Net Centric Operations and FORCEnet. Each of the eight enabling technologies was examined to identify shortfalls that could prohibit successful Net Centric Operations. The document that can be found on the ONR web site (Reference 1) has over 108 footnotes that discuss potential limitations, ongoing R&D and possible solutions. The document lists over 200 S&T shortfalls. Feedback on this Technical Taxonomy is welcomed.

The following is an example of the Technical Taxonomy. Each section of the Technical Taxonomy describes an enabling technology area, such as decision support systems, that is shown below. There is a brief explanation about the meaning of the technology area (in this case decision support systems). The document then identifies limitations that need to be overcome to support Naval NCO. This particular example is from Section 5, the Automated Adaptive Planning portion and the first entry, Section 5.1 addresses Decision Support Systems. The actual paragraph numbers from the technical taxonomy are included as part of this example.

"5.1 Decision Support Systems

Automated intelligent machine capabilities to work with operators, machines and sources of information to produce and adjust planning in support of battle management execution, command and control, resource allocation and logistics.

5.1.1 Current systems are manpower intensive and cannot adjust to changing operational conditions in a timely manner.

5.1.2 There is little feedback and little support for the discovery process.

5.1.3 Unable to coordinate distributed planning processes that automatically adapt to a changing operational scenario with current systems.

5.1.4 Current real time systems do not interface very well with near real time planning systems and validated M&S systems.

5.1.5 There are a number of S&T issues including limitations on computing platforms to perform deterministic operations research optimization algorithms as well as the real-time access to resource states in optimizing or

dynamic repair of mission plans. Maintenance and resource allocation systems are typically unavailable to mission planners while performing alternative courses of action. Other issues are correlated to earlier sections of the technical taxonomy to include how mission planning data is transmitted or shared across platforms. In most cases, good metrics are required to determine operational success. "

The portion of the taxonomy shown above would contain footnotes that amplify descriptions and limitations. As another example, Information Distribution Management, Section 2, is addressed below. The taxonomy amplified the meaning of Information Distribution Management, identified functional shortfalls caused by technology limitations and then provided critical S&T needs.

- Network-Centric Vision Objective
  - Automatically provide the right information at the right time
  - Eliminate unnecessary distribution and delivery of information
  - Assist user in dealing with information from a wide variety and large number of sources
- Functionality Shortfalls Due to Technology Limitations
  - Information systems usually do not understand context of user needs
  - Users get little help dealing with information diverse needs
  - Tendency toward information overload
  - Inability to manage user subscription to information in near real time
  - Inability to merge information across semantic differences
  - Diverse presentation methods of information from diverse sources inhibits understanding and correlation

- Some Critical S&T Needs
  - Interoperability software
  - Information access and delivery software
  - Computer aided reasoning for task-oriented information dissemination
  - Automatic association and merger of information for unified presentation
  - Automated recognition and cueing for significant patterns of information
  - Adaptable viewers and Human-Machine Interfaces

The remainder of the NCO Technical Taxonomy addresses the other 6 enabling technology areas in a similar manner. Feedback is welcomed on the Technical Taxonomy

3.0 Summary and Conclusions

Net Centric Operations capabilities are a key ingredient to transformation. A Technical Taxonomy associated with Net Centric Operations has been developed to allow the NCO community to identify operational needs, associated functional capabilities, enabling technologies and potential shortfalls. This approach provides a common language and view that will assist the S&T community to address NCO investment and prioritization.

The S&T shortfalls that were identified by the Navy are very consistent with $&T thrusts as discussed at March, 2004 DARPATECH

4.0 References

1) ONR web site, http://www.onr.navy.mil/02/baa/expired/03_007/default.asp

2) Sea Power 21 Series—Part V "ForceNet: Turning Information into Power", Vice Admiral Richard W. Mayo, U.S. Navy, and Vice Admiral John Nathman, U.S. Navy *Proceedings*, February 2003

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Customer Success Is Our Mission

S&T Implications for Net Centric Operations

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16 June, 2004
CCRTS Conference

Agenda

- Network Centric Operations (NCO) Infrastructure
- NCO and FORCEnet
- NCO Taxonomy of Technology Limitations

Defining the NCO Infrastructure Objectives and Required S&T

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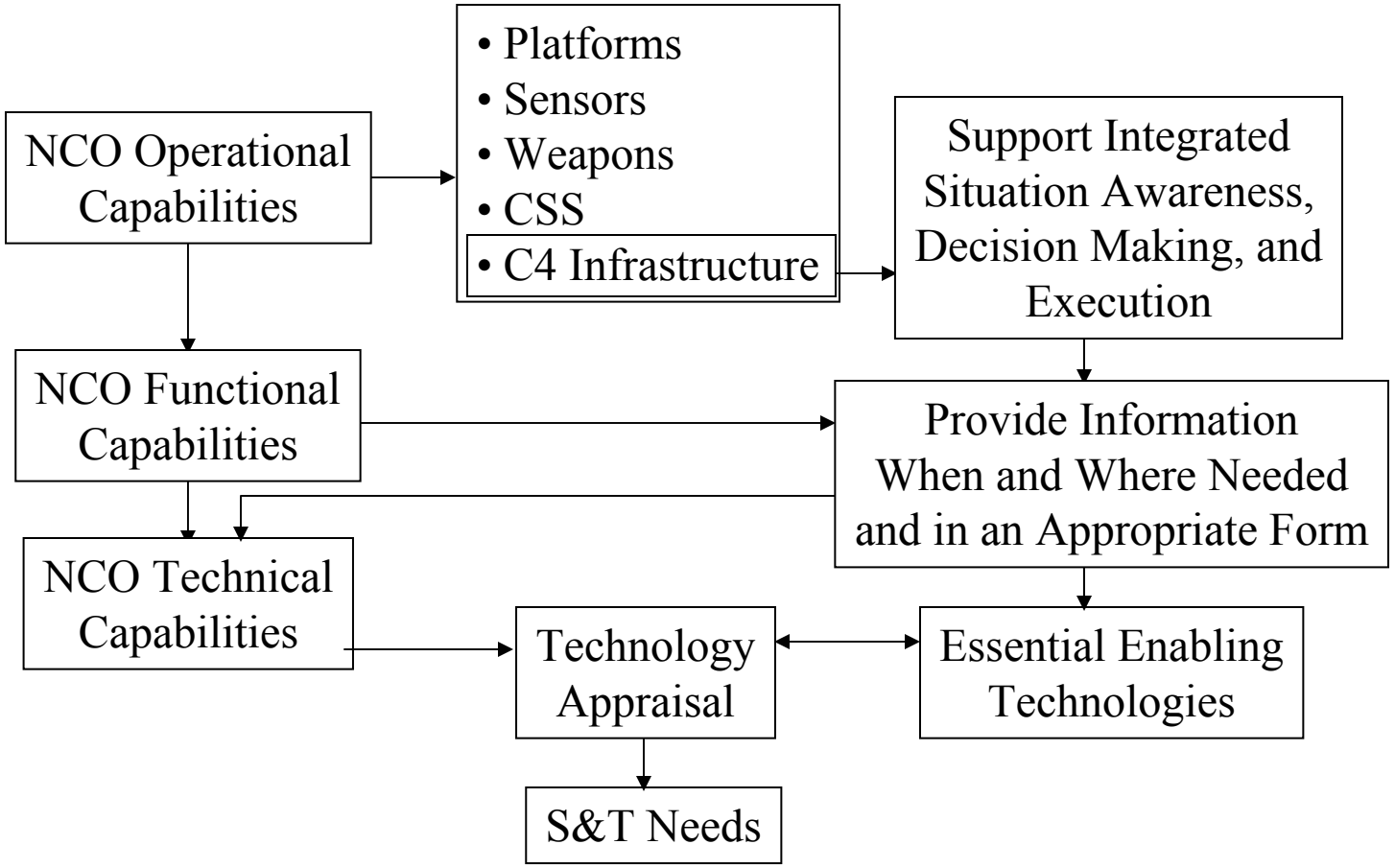

FORCEnet Engagement

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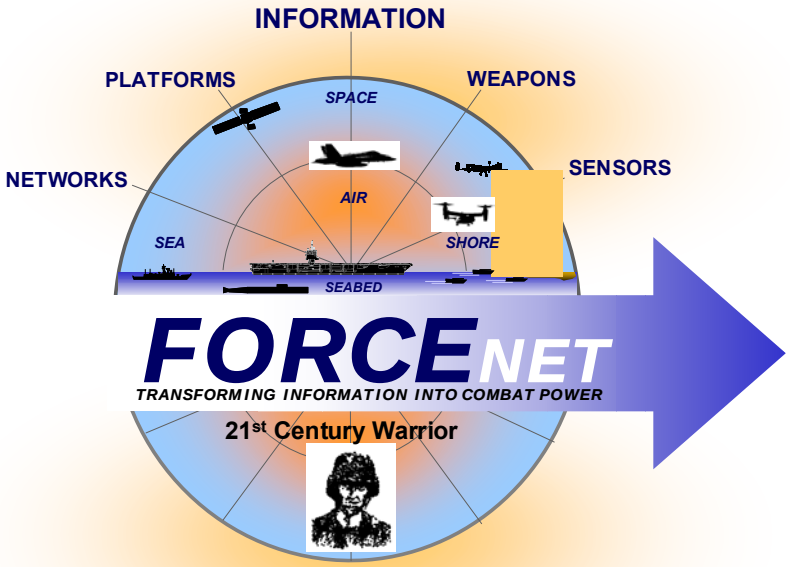
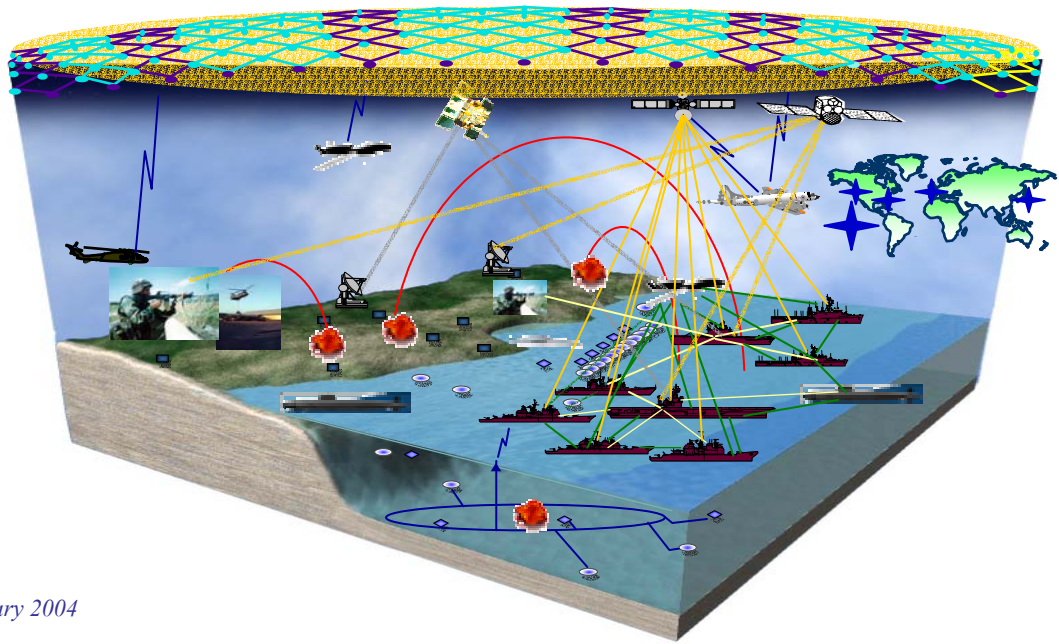


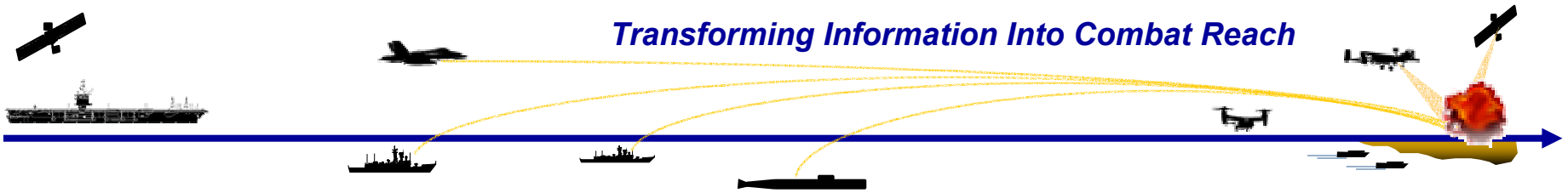


19 February 2004

CAPT Joe Giaquinto, USN

Maj Woody Hesser, USMC

LCDR Dan Rieken, USN

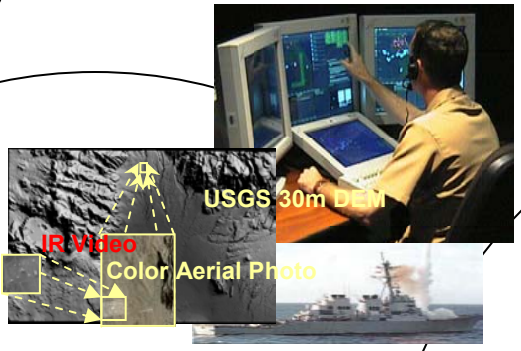


Network Centric Operations (NCO)

Taxonomy of Operational Level Functions

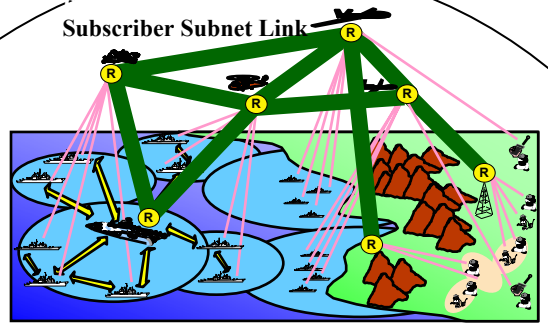
Situation Awareness and Understanding

- Consistent understanding of the situation by all elements of the force, with tailored views according to need



Planning and Force Management

- Development of courses of action for all warfighting and support functions, with force-wide deconfliction and coordination of intended actions and with continuous replanning and adjustment synchronized with ongoing execution



Direction, Action, Synchronization, and Control

- Execution of missions and tasks concurrently with planning and replanning, including self-synchronization of own actions with those of other elements of the force

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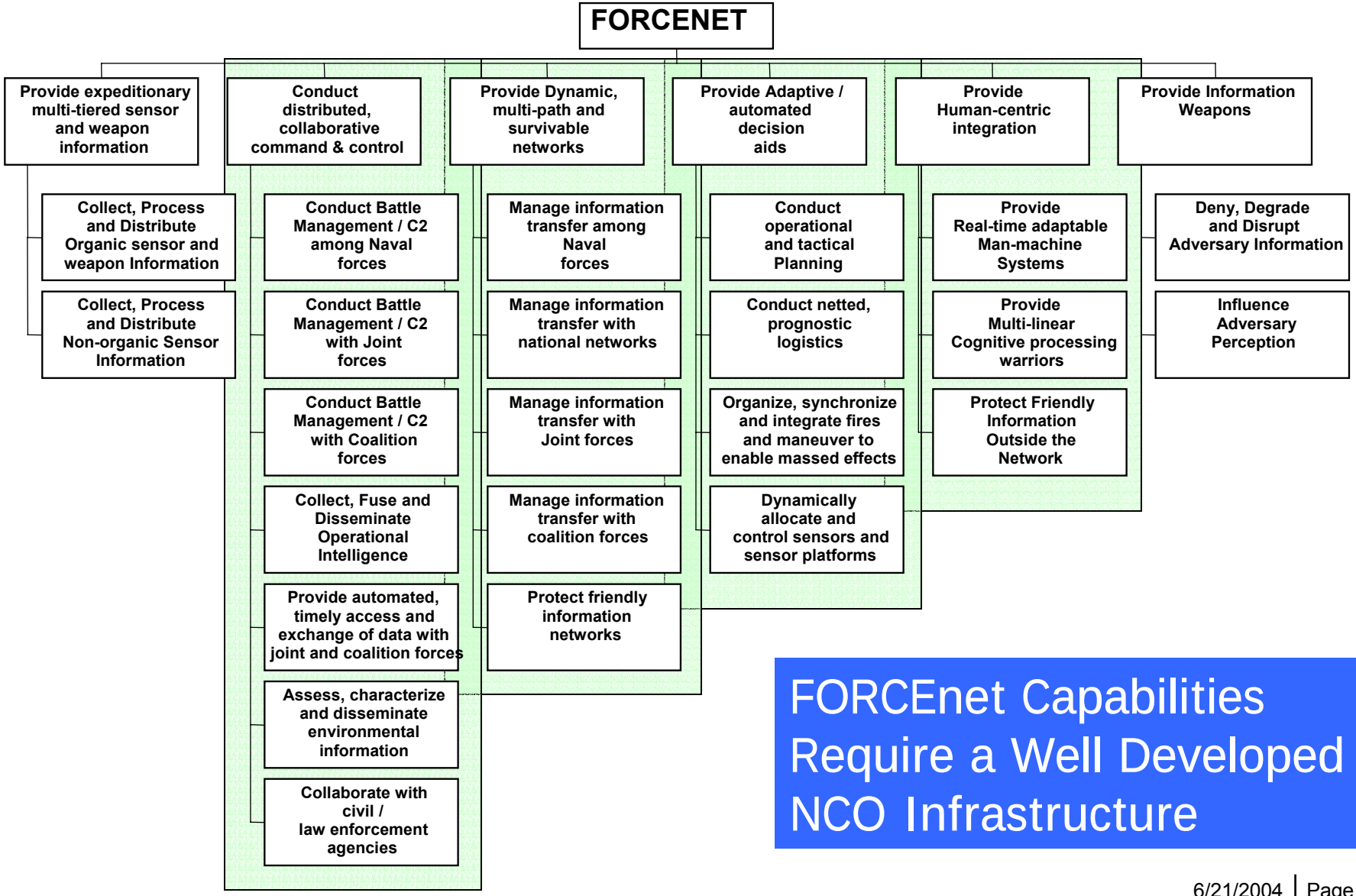
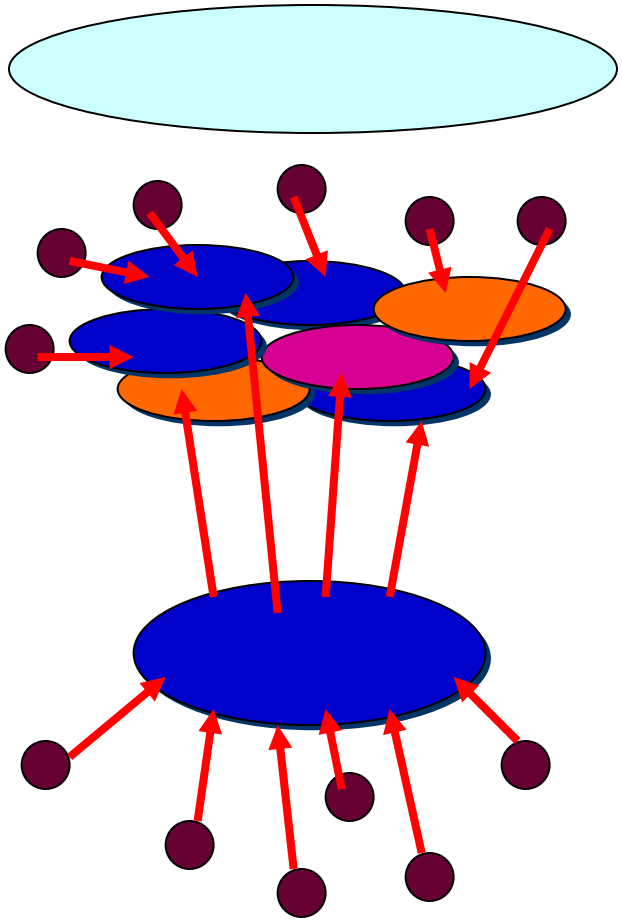
FORCEnet Capabilities Map



FORCEnet Capabilities Require a Well Developed NCO Infrastructure

The Solution-Space



Concepts, CONOPS

Capabilities, expressed in terms of the desired battlespace effects

Capabilities, expressed in terms of what's being enabled by FORCEnet

Capabilities, expressed in terms of FORCEnet

Technologies & technical solutions +
Concepts, CONOPS, and non-mat'l solutions

Current Problem Space

TST Example

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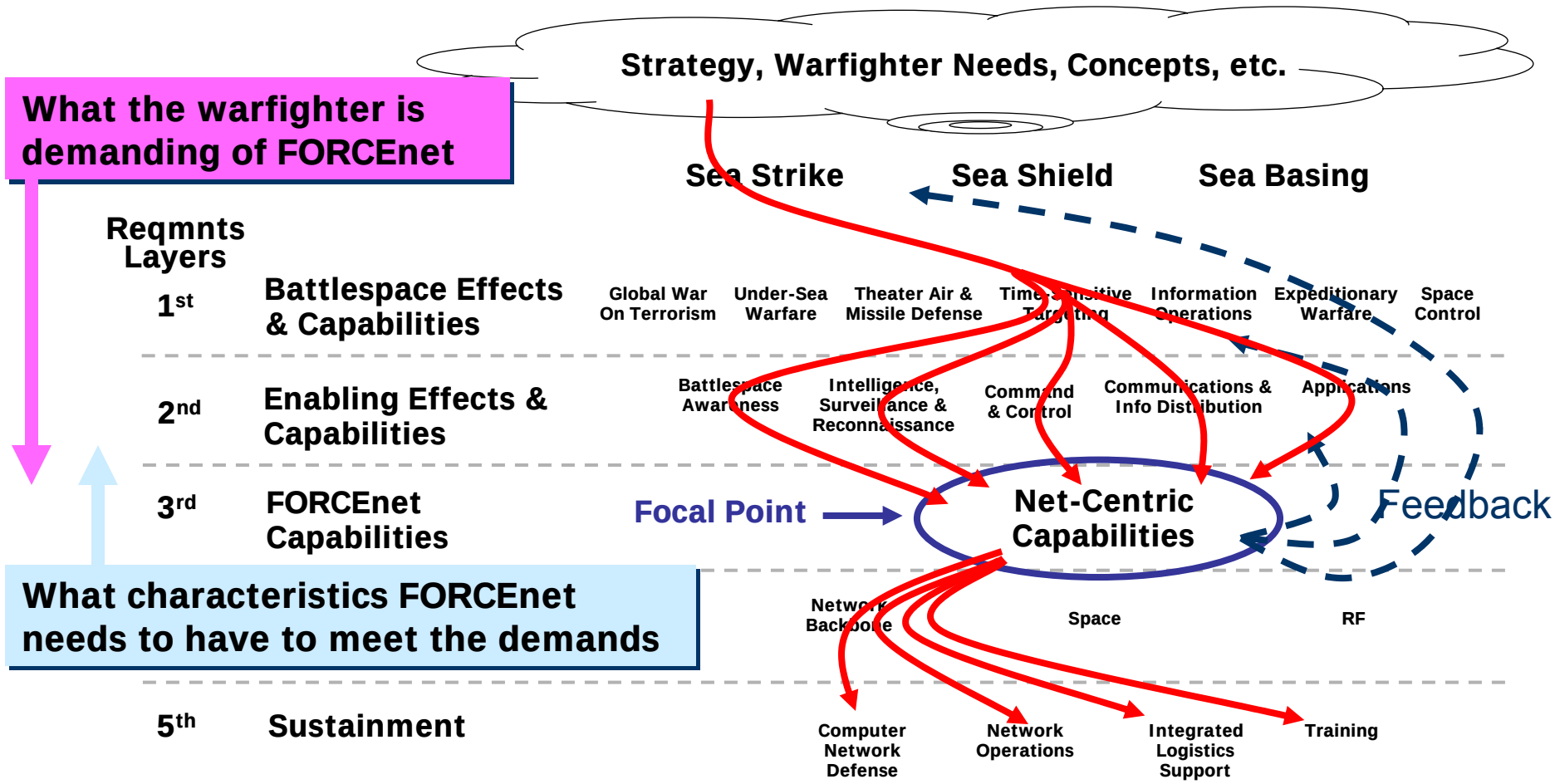
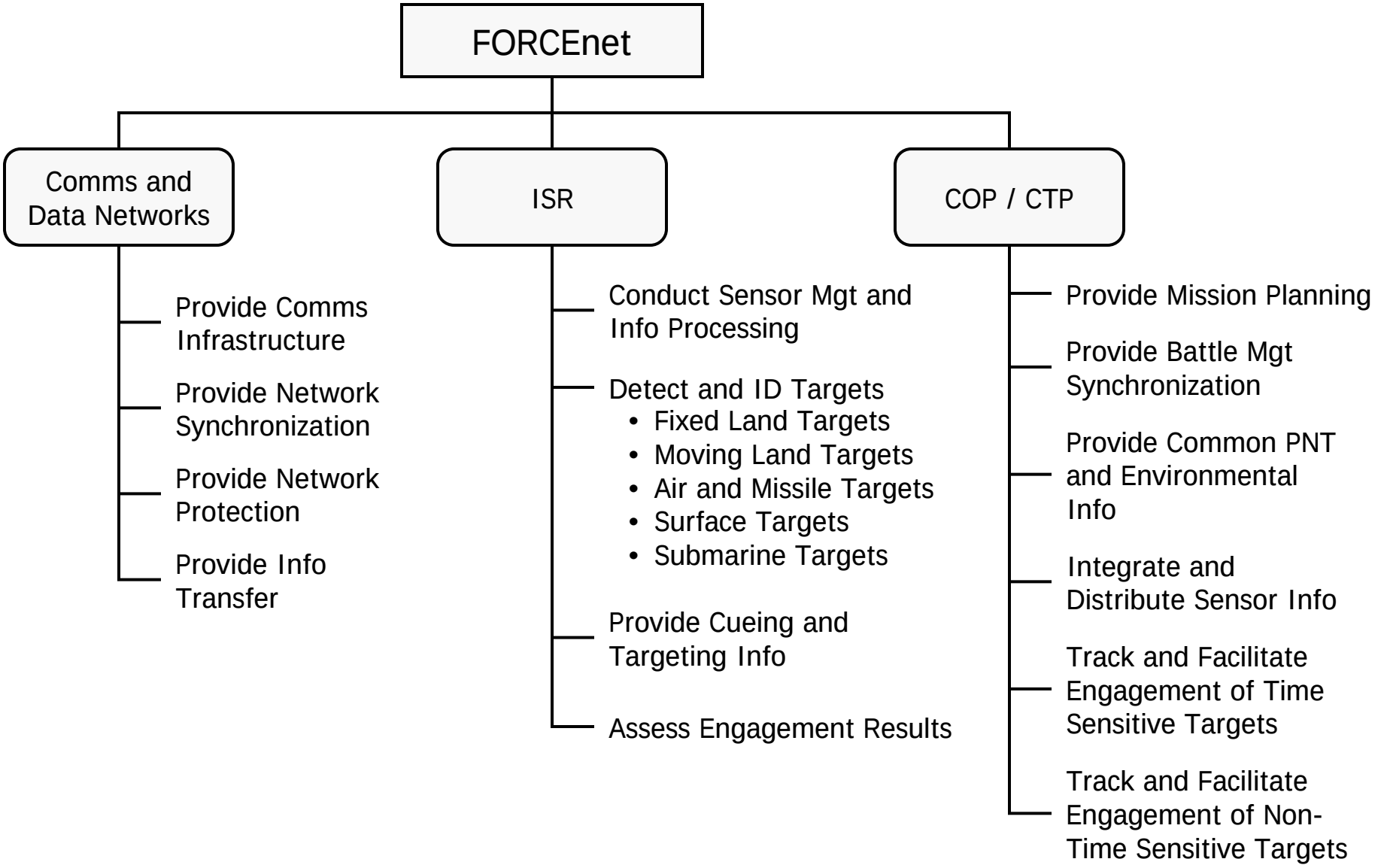


In order to understand the desired capabilities of the enablers …
… we need to understand the needs of the "enabled"

Fn Capability List, May 03



The Revised (POM06) Taxonomy

Sea Power 21

Sea Basing

- Enhanced Afloat Positioning of Joint Assets
- Sea-based Command & Control
- Integrated Joint Logistics
- Accelerated Deployment & Employment Timelines

Sea Strike

- Expeditionary Strike Forces
- Expeditionary Maneuver Warfare
- Time-Sensitive Strike
- Clandestine-enabled & Covert Strike
- Integrated EW/IO & Kinetic Strikes

Sea Shield

- Theater Air & Missile Defense
- Littoral Sea Control:
  - Mine Warfare
  - Anti-Sub. Warfare
  - Surface Warfare
- Homeland Defense & Littoral Force Protection

Key Enabling Capabilities
(to be provided by FORCEnet)

- *Fully interoperable, integrated USN / USMC C^4ISR and combat support IT, including:*
  - ** Node-addressable, robust, high-capacity network across the dispersed Sea Base, to Strike / Shield assets, and ashore*
  - ** ISR correlation, and a shared COP / CTP*
  - ** Dynamic C^2/Battle Management, info mgmt, mission planning & rehearsal, and collaboration capabilities — across staffs hosted on the sea-base and ashore*
  - ** Information assurance*
- *Flexible interfaces and hosting of the above functions for the full range of Joint assets*

- *Networking, ISR, C2/BM, info mgmt, and related capabilities (as per Sea Basing)*
- *Naval / Joint force-wide digital fires network*
- *New ISR sources and methods to locate and characterize covert, unconventional, and underground targets (pre & post strike)*
- *Pervasive, continuous tracking of key threats ashore and all sea surface traffic*
- *Sensing and networking quality to permit selective use of the sensor grid for fire control*
- *Classified offensive EW/IO capabilities*
- *Appropriate interfaces to enable covert strike*

- *Networking, ISR, C2/BM, info mgmt, and related capabilities (as per Sea Basing & Strike), plus support rapid, joint TAMD decision-making and regional, beyond-line-of-sight intercepts*
- *New ISR sources and methods to:*
  - ** Benchmark the littoral undersea environment at ultra-high resolution, and detect changes*
  - ** Monitor the full life-cycle of adversary mine warfare activities, esp. laying operations*
  - ** Detect, locate & track AIP-equipped subs over large areas (i.e., equal to ASCM ranges)*
  - ** Provide fire-control against in-bound torpedoes and mobile mines*
  - ** Detect emerging / converging FPB swarms*
  - ** Discriminate terrorist boat and missile threats in the harbor / coastal clutter environment*
- *Interoperable C4ISR interfaces to IC & DHS systems*

Information & Knowledge Advantage / FORCEnet

- Expeditionary, Multi-tiered Sensor & Weapon Grid
- Dynamic Command and Control, Information Management, & Collaboration
- Dynamic Networks
- Integrated Information Operations & Assurance

What Is The Taxonomy?

- A hierarchical taxonomy of the information technologies that support Network Centric Operations and FORCEnet. Associated with each technology is a short list of their current limitations that could inhibit achieving network centric and FORCEnet capabilities.
  - 202 limitations identified to date by the ONR Network Centric Operations Working Group

Purpose

- Provides an examination of *eight technology areas* that are required to support *five enabling functions* necessary for Network Centric Operations and FORCEnet. These five enabling functions are:
  - *Universal, seamless, robust communications, connectivity and network service management*
  - *Assured information integrity*
  - *Effective information processing assessment, sharing/collaboration, presentation, and navigation*
  - *User focused information management and dissemination/communications*
  - *Empowered disadvantaged personnel and systems*

Taxonomy Technology Areas

- The *eight technology areas* to support the enabling functions are:
  - *Reliable communications and infrastructure management*
  - *Information distribution management*
  - *Geographically distributed, computing infrastructure*
  - *Situation understanding*
  - *Automated adaptive dynamic planning*
  - *Human machine interface*
  - *Information assurance and information operations*
  - *Modeling and simulation*

Taxonomy Technology Areas Sub-Groups

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- Reliable communications and infrastructure management
  - Data Transport and Transmission Systems/Data Links
  - Networking
  - Infrastructure and Computational Resource Management
- Information distribution management
  - Interoperability Software for (for legacy networks)
  - Information Access and Delivery Software
- Geographically distributed, computing infrastructure
  - Electronic Devices and Components (disadvantaged user and remote sensors
  - Adaptive Network Computing Management and Services
  - Power Sources (disadvantaged user, autonomous vehicles and remote sensors)

Taxonomy Technology Areas Sub-Groups (cont.)

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- Situation Understanding
  - Information Integration Fusion and Correlation for current ISR systems, sensors and open sources
  - Computer Aided Inferencing and Reasoning
  - Autonomous Intelligent Vehicles and Platforms
  - Collaborative Environment
  - Pervasive Computing/Ubiquitous Computing
  - Remote Equipment Diagnostics
  - Augmented Reality
- Automated Adaptive Dynamic Planning
  - Decision Support Systems
  - Cooperative Software Agents
  - Autonomous Intelligent Vehicles and Platforms

Taxonomy Technology Areas Sub-Groups (cont'd)

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- Human-Machine Interface (including disadvantaged users)
  - Visualization of Operational Situations and Plans
  - Explanation Agents
  - Alerting and Cueing Agents (for system monitoring and control)
  - Natural Language and Foreign Language Understanding
  - Hands-Free Human-System Interface
  - I/O in Stressing Environments (Noise, Motion,etc.) for Mobile Field Operators
  - Computer Aided Reasoning
  - Augmented Reality

Taxonomy Technology Areas Sub-Groups (cont'd)

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- Information Assurance and Information Operations
  - Confidentiality
  - Authentication
  - Audit and Analysis of Network Activities
  - Integrity
  - Network Traffic Processing and Data Base Interaction Analysis
  - Ensuring Trusted Systems
  - Offensive Information Operations
  - Computer Aided Reasoning/Pervasive Computing
  - Detection of Covert Information
- Modeling and Simulation
  - Situation Awareness
  - Course of Action Evaluation
  - Interoperability

Example of Technology Area and Limitations

5.1 Decision Support Systems

Automated intelligent machine capabilities to work with operators, machines and sources of information to produce and adjust planning in support of Battle Management execution, Command and Control, resource allocation and logistics.

5.1.1 Current systems are manpower intensive and cannot adjust to changing operational conditions in a timely manner.

5.1.2 There is little feedback and little support for the discovery process.

5.1.3 Unable to coordinate distributed planning processes that automatically adapt to a changing operational scenario with current systems.

5.1.4 Current real time systems do not interface very well with near real time planning systems and validated M&S systems.

5.1.5 There are a number of S&T issues including limitations on computing platforms to perform deterministic operations research optimization algorithms as well as the real-time access to resource states in optimizing or dynamic repair of mission plans. Maintenance and resource allocation systems are typically unavailable to mission planners while performing alternative courses of action. Other issues are correlated to earlier sections of the technical taxonomy to include how mission planning data is transmitted or shared across platforms. In most cases, good metrics are required to determine operational success.

Extract from NCW WG "Taxonomy of Technology Limitations to Support the Five Enabling Functions Required for Navy Network Centric Operations", version 7.0, May 2003

How The Taxonomy Is Used

- A S&T investment decision aid
  - Helps map operational capabilities to technology needs
- ONR Discovery and Invention (D&I) projects that relate to FORCEnet will be reviewed against the Taxonomy limitations in order to determine potential S&T solutions and future S&T investment

Making FORCEnet Real Requires Naval S&T Investments

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- Relevant COTS technologies frequently offer desirable FORCEnet capabilities, but often they are intended for less stressing and severe commercial applications, resulting in unacceptable robustness and QoS for Naval operational settings.
- Substantial modification and tailoring (6.2 & 6.3 investments) of COTS technologies are usually required to make them suitable for Naval operational use.
- Relevant COTS technologies are often predicated on high-speed, physically-connected networks, not disadvantaged wireless links that Navy operates.

Making FORCEnet Real Requires Naval S&T Investments (cont.)

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- Substantial S&T investments needed to integrate Naval legacy systems into FORCEnet are not likely to come from industry or other Government sources.
- Some key FORCEnet-required technologies (such as those that generate Common Picture) have small or non-existent commercial markets, thus requiring Naval S&T development effort.
- Science base for many FORCEnet-required technologies has historically been advanced primarily by DoD, not commercial, investments. Many commercial and DARPA-sponsored FORCEnet technologies were instigated by ONR investments.

Making FORCEnet Real Requires Naval S&T Investments (cont.)

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- ONR-led research currently paces industry and Government in many key FORCEnet science and technology areas, e.g., :
  - Mobile, wireless, computer networks that integrate afloat and ashore components
  - Sensor image processing
  - Autonomous systems
  - Distributed resource optimization
  - Common Picture Interoperability
  - Time-sensitive decision-making with uncertainty constraints

Taxonomy Limitations

Information Distribution Management (including Processing & Presentation)

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- Network-Centric Vision Objective
  - Automatically provide the right information at the right time
  - Eliminate unnecessary distribution and delivery of information
  - Assist user in dealing with information from a wide variety and large number of sources
- Functionality Shortfalls Due to Technology Limitations
  - Information systems usually do not understand context of user needs
  - Users get little help dealing with information diverse needs
  - Tendency toward information overload
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  - Inability to merge information across semantic differences
  - Diverse presentation methods of information from diverse sources inhibits understanding and correlation

Information Distribution Management (including Processing & Presentation)

- Some Critical S&T Needs
  - Interoperability software
  - Information access and delivery software
  - Computer aided reasoning for task-oriented information dissemination
  - Automatic association and merger of information for unified presentation
  - Automated recognition and cueing for significant patterns of information
  - Adaptable viewers and Human-Machine Interfaces

Reliable Communications & Infrastructure Management

- Network-Centric Vision Objective
  - Grid resources and services are dynamically optimized to meet current operational priorities
  - Management is achieved automatically by software agents that respond to policy, doctrine, and current operational status
- Functionality Shortfalls Due to Technology Limitations
  - Management is confined to the platform level. No ability to coordinate management across the grid
  - No ability to quickly reallocate grid resources in synch with Op tempo
- Critical S&T Needs
  - Software to Automatically reconfigure grid resources to meet current operational priorities
  - Automated adaptation of applications to contend with grid stress and degradation
  - Grid monitoring and assessment tools for manual oversight of QoS management

Situation Understanding

- Network-Centric Vision Objective
  - Provide coherent set of information services for the warfighter
  - Provide fault tolerant collaborative applications
  - Provide Multi-level and Multiple level access to collaborative sessions
- Functionality Shortfalls Due to Technology Limitations
  - Limited ability to support COTS collaborative applications in a Tactical Grid
  - Limited ability to accommodate semantic and application heterogeneity
- Critical S&T Needs
  - Timely, accurate information and sensor fusion from heterogeneous sources
  - Fault tolerant software appliqués for COTS collaboration applications over tactical radio nets
  - Interoperability software to support sharing of information and applications across diverse systems
  - Software to support collaboration among users with different applications, different forms of presentation and I/O, and different security levels

S&T Investments to Enable FORCEnet

Raytheon

Science or Technology Need	D&I	E&D	Science or Technology Need	D&I	E&D
• Cheap, ubiquitous Phase Array comm antennas		X	• Real-time planning of ISR and comm priorities & tasking	X	
• Quality of Service for warrior control of comm use	X	X	• Advanced radar detection sensors		
• Advanced control of distributed sensor networks	X		• Network defense that won't interfere with warfighters	X	
• Absolute data integrity assurance	X		• Real-time cognitive-aiding display of info	X	
• Planning algorithms for real-time coordination of highly distributed forces	X	X	• Multi-sensor and multi-intelligence source data correlation, cross-cueing	X	
• Multi-hypothesis tracking algorithms	X	X	• Absolute Combat ID, maintain warfighter covertness		
• Augmented reality registered to world view	X		• Network real-time visibility and control	X	
• Rule sets to automatically meet evolving warfighter land warfare support network management priorities	X		• Automatic summary of multi-media info content (multi-language) presented in most useful form for individual		
• Over the horizon(320 km range) comm independent of satellites		X	• Automated management of electromagnetic radiation to eliminate Hazard of EM Radiation to Ordnance (HERO)	X	
• Low probability of detection, low probability of intercept			• Dynamic multi-casting of battlefield information		
• On-the fly network/subnetwork setup and mobility; dynamically mapped to mission needs in real time	X		• Improve speed and accuracy of Orient, Decide, Act part of OODA loop		X
• Software to infer warfighters' information needs	X		• Threat assessment, real time, for all types of threat	X	X
• Stochastic modeling of operation patterns to predict trends, coupled with data fusion & analysis tools	X		• Collaboration across multiple security domains, limiting collaborators' ability to their role and mission		X
• Stable operational platforms in situations of intermittant connectivity, supporting auto language translation & complex, nonlinear, interactive processes	X		• Agents to mediate uncertainty, cultural differences, situation differences		
• Automated launch of information & comm service based on situation	X		• Automated command center sync on land battlefield		
• Automated troop sync for dismounted troops			• Brilliant control of power demand to reduce power need		
• Automated reporting within echelon & up-echelon		X	• Distributed hierarchical processing to reduce comm needs		
• Auto target recognition, multi-media mapping	X		• Fast, automatic transfer of multi-media info among security enclaves		

"X" indicates ONR work in progress